Big Data Issues in SDN Based IoT: A Review

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Abstract. IoT infrastructure is resource and energy constraint. The emergence of a smart world has led to the interconnection of diverse objects with the Internet which leads to the generation of a tremendous amount of data which can be referred to as Big Data. Since the IoT is going to be expanded in a exponential manner, Big Data Issues becomes a threat for its faithful operation. Other than this, the existing IoT architecture has limitations with respect to scalability, reliability, availability, etc. To overcome these limitations along with resolution of Big Data issues, investigators proposed different types of architectures for its improvement. In this paper, we have tried to highlight the evolution of conventional IoT architecture to SDN based IoT architecture which offers better provisions to resolve Big Data issues also. This review paper also highlights the procedures, developed by investigators of the area, as to how Big Data issues can be resolved in these architectures. Further research scopes arising out of the present endeavor are also been highlighted which will provide the direction of future research in the area.

Keywords: Big data · Big Data issues · Data analytics · Internet of Things · Software defined network

1 Introduction

The number of smart devices connecting to the Internet is increasing day by day. This demands the leverage of Big Data analytics processes in order to achieve the full advantage of the services provided by the Internet of Things (IoT). IoT is one of the major sources of generating a huge amount of data [1]. According to Cisco, Machine to Machine (M2M) connections will be more than half of the global connected devices and connections by the year 2022. The share of M2M connections will grow from 34% in 2017 to 51% by 2022 [2]. As the number continues to grow, the problems of collecting such huge amount of data, its analysis and transmission of the same to the cloud for storage becomes more challenging. The real issues concerning Big Data in IoT originated from the resource-constrained configuration of IoT and heterogeneity of the data sources associated with IoT. Moreover, accurate and real-time analysis of the data in the shortest possible time is also necessary for the prompt action of the actuators employed. Proper network utilization should also be considered so that maximum optimization is obtained.

The Big Data issues in conventional IoT system is difficult to resolve as it is resource-constrained. Solutions for Big Data issues requires formidable computational power. This

© Springer Nature Switzerland AG 2020
R. Patgiri et al. (Eds.): BigDML 2019, CCIS 1317, pp. 72–82, 2020.
https://doi.org/10.1007/978-3-030-62625-9_7

is not possible in IoT devices. So, it can be resolved in the Cloud level which may have many difficulties with respect to the commercial point of view, security point of view etc. Therefore, many competing IoT architectures have been proposed to resolve this difficulty along with many other bottlenecks existing in the conventional IoT system. The significant characteristics of IoT data in cloud platforms are briefly mentioned in [3]. A basic conventional architecture of IoT is shown below in Fig. 1.

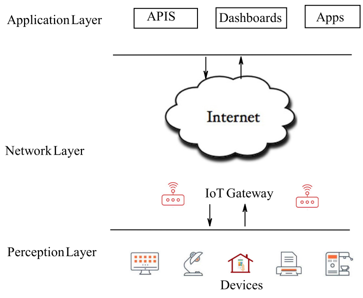

Fig. 1. Simple IoT architecture.

The main difference between conventional and SDN based IoT system is the resource-constrained gateways of IoT system which can be replaced by Controllers [4]. This controllers are powered with more computational resources. So, some of the Big Data issues can be resolved here itself. Big Data issues would become a bit feasible if the conventional IoT system could be upgraded to Software Defined Network (SDN) based IoT. Therefore, resolving Big Data issues in SDN based IoT system has now become a potential research issue both from academia and industry. SDN is a concept which gives a new dimension to the existing network by decoupling the control and the data plane. It has several advantages especially for Big Data analysis of IoT. The conventional networks are increasingly adopting the SDN architecture for its ability to program the network [5].

Data extracted from different environment serves as a very important component in decision-making processes for various Industrial operations. Nowadays, data collected from different sources have increased tremendously including IoT system and it is now in the order of petabytes and zeta bytes in volume. According to a report by the International Data Corporation (IDC), the estimated global data volume will increase by a factor of 300, from 130 EB in 2005 to 40,000 EB in 2020, which amounts to double the growth every two years [6]. Additionally, the nature of this data is of highly complex. It can be safely termed as Big Data. Big Data exhibits some distinct characteristics.

Big Data can be defined by five V's [7] namely-Volume, Velocity, Variety, Veracity and Value. The common processes involved in Big Data utilization is given by Zhang et al. in [8]. With proper analytical tools, time series data can provide valuable insights into the dynamics of the process whose time series data has been that will help in taking precise decisions. IoT system produces Big Data whose solution is becoming very difficult due to a lot of constraints in the IoT system. Table 1 exhibits the difference between conventional data and Big Data.

Table 1. Comparison of Traditional Data and Big Data.

Comparison parameter	Traditional data processing	Big data processing
Rate of data	Slow	Rapid
Storage feasibility format	Feasible structured	Unfeasible
Data source	Mostly centralized	Semi-structured and unstructured
Mode of operation	Interactive/Offline	Fully distributed
Accuracy	Approximate	Batch/Real time
		Accurate

One of the standard methodology to solve Big Data problems is Hadoop based approaches. An open-source platform or framework that serves as a solution to the storage and the processing of Big Data is Apache Hadoop [9]. It runs on clusters of commodity servers that can support the storage and processing of the massive data. The main components of the Hadoop architecture are Hadoop Distributed File System-HDFS, YARN, MapReduce and Hadoop Common [10]. HDFS allows the unstructured as well as structured data to be stored in a distributed fashion across the clusters. It consists of a single Name Node and multiple Data Nodes. YARN performs the necessary resource management tasks such as scheduling jobs. MapReduce consists of the two phases i.e. Map and Reduce phases. In Map phase, data are split into proper format (key/value pairs) and then analyzed to produce sub-results. In the reduce phase, these sub-results are combined to give the final result. Hadoop Common is a set of shared utilities and libraries that provide the underlying capabilities required. Hadoop supports a range of processing frameworks to extend its basic capabilities like Apache Pig, Apache Hive, etc.

Due to the complex characteristics of Big Data, traditional systems are inadequate to handle the huge data sets. The main challenges in the Big Data analysis are storage, transmission, efficient tools and finally presenting the results in proper formats for various decision-making and other tasks. This paper deals with different methodologies adopted by earlier researchers to deal with Big Data problem on the SDN based IoT platform.

The remainder of the paper is as follows. In Sect. 2, an SDN based IoT-Big Data architecture have been examined. In Sect. 3, existing related works are reviewed and analyzed. Section 4 presents the Big Data challenges and issues in the present scenario. Section 5 identifies the future scope in this area. Finally, Sect. 6 concludes the paper.

2 SDN Based IoT-Big Data Architecture

A simple IoT based architecture is shown in Fig. 1. A few SDN based IoT-Big Data analysis architectures can be found in the literature. Figure 1 and Fig. 2 will help in distinguishing the difference between them.

The architecture as shown in Fig. 2 provides an overall abstraction of the system. The Infrastructure layer consists of the IoT layer and the network layer. The sensors and other devices reside in the IoT layer. The Network layer consists of the network elements like routers, switches, etc. The Infrastructure layer is also called the data plane

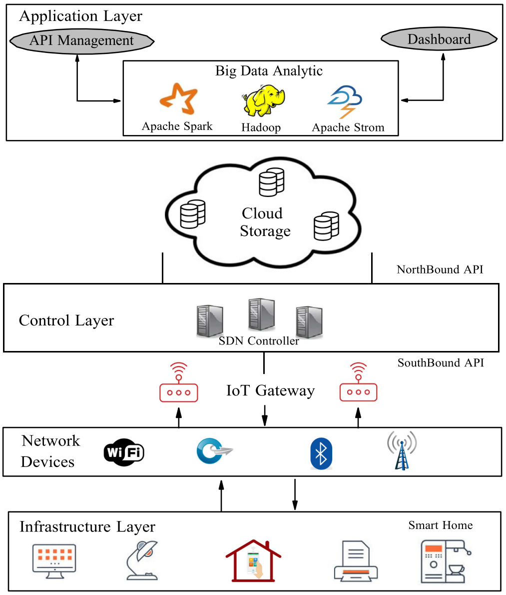

Fig. 2. Architecture of SDN-IoT with big data analytics [6, 11].

for SDN network. The Control layer is placed above the Infrastructure layer that helps to dynamic configuration of the network. The Control layer interacts with the network elements through the South-bound Interface (SBI) [6]. One of the most commonly used SBI protocol used is 'OpenFlow'. The SDN controller can be of either open-source or commercial based such as NOX, POX, FloodLight, Ryu, Open Day Light, Beacon, etc. The Application layer is placed on the top. It consists of various applications and Application Programming Interface (APIs) to direct the network and check its status. The SDN controller interacts with the Application layer using the North-bound Interface (NBI). The Big Data analytics framework resides in the application layer that makes the decision-making process and other complex analytical processes [11]. Big Data application architecture for smart cities using SDN based IoT has been proposed by Din et al. in [12]. It consists of four layers with three main levels and two intermediate levels as shown in Fig. 3.

The smart services like smart home, smart transportation, smart healthcare, etc. produce an enormous amount of data from IoT sensor-embedded devices which are gathered and passed on to the upper layer using the intermediate level i.e. an SDN based network. SDN controller identifies the sensor data, manages the application-based routing as well as check for congestion in a link. At the Data Processing and Management Level, meaningful data can be extracted using a framework like Hadoop Distributed File System to store and manage the data. Cluster-based Hadoop System can be used for processing huge data. Applications such as GraphX and SPARK can be used for real-time data processing.

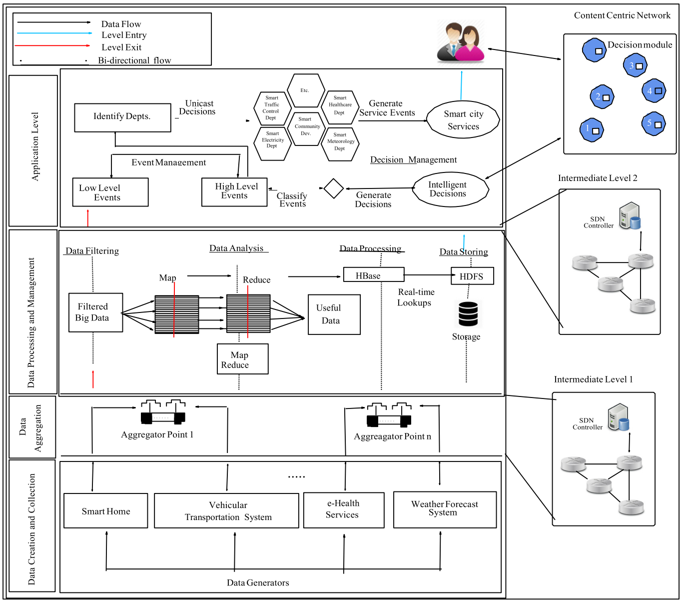

Fig. 3. SDN based IoT architecture for big data analysis in smart cities [12]

3 Literature Review

In this section, some of the current research works and their contributions to address the problems associated with Big Data generated by IoT have been discussed.

Big Data in IoT: A basic mathematical analysis was presented in [13] by Ding et al. to give a practical approach to the Big Data processing in IoT. They have focused on four massive data processing encountering the issues - the heterogeneity of data generated by IoT devices, the non-linear processing of Big Data, the multi-dimensional aspect of data processing and the decentralized and parallel processing of the data. The information will open more practical researches in this direction. The authors of [14] have described the varieties of Big Data generation by IoT and support for localized and real-time analysis can be addressed by the fusion of data which yields better data analysis. Existing data mining algorithms as well as improved clones have proved to be helpful in the Big Data analysis process. In [15], the authors Alam et al. have experimented the applicability of existing data mining algorithms in simpler IoT datasets and has found to have higher accuracy. However, the algorithms were computationally expensive and some investigations are required to reduce it. In [16], the authors Dineshkumar et al. proposed a system of Big Data analysis on health data using Hadoop and map reduce. Big Data analysis in healthcare is of significant importance both for the patient as well as doctors. In [17], the authors Kang et al. presented an implementation model of RFID/ sensor data repository using MongoDB, which is a popular document oriented database, and a shared key that increases query response time and offers a uniform data distribution in servers. The model can store huge amounts of data produced by RFID-IoT sensors and the system is efficiently utilized especially for supply chain management. The proposed model might need more work for some exceptional cases as mentioned by the author. An adaptive scheduling algorithm [18] had been proposed by Ghoneem & Kulkarni to reduce the execution time of Hadoop MapReduce in a heterogeneous and scalable environment. A classification algorithm is used to differentiate executable and non-executable jobs and process them accordingly. Issues like small job starvations are solved.

Smart City: Din et al. [12], the authors proposed architecture for smart cities using SDN enabled IoT-Big Data processing. Here, Hadoop clusters were used and modification to existing scheduling algorithm was done to adjust the computational load dynamically in a distributed environment. Thus, the given methodology helped to speed up the data pre-processing and analysis part further under resource constraint environment using the distributed computational environment. In the paper [19], authors Bi et al. proposed an IoT system based on SDN for smart city services. Experimentation was done to study time-constrained Big Data transfer scheduling problem. The proposed methodology helped in achieving lower transfer delay and improved network bandwidth utilization. This is accomplished by employing an SDN controller that allows dynamic flow control and scheduling the multi-flow transfer.

SDN-Based IoT for Big Data: The authors Kakiz et al. [20], proposed an SDN-based IoT architecture where sensor data are analyzed in the lower layer instead of the application layer to reduce traffic. It consists of four layers namely, perception, gateway, network (with a sub-layer called Controller Service) and application layer. OpenFlow gateways were used as gateways. Here each incoming packet received from the perception layer were evaluated to judge its usefulness.

If packets were found to be useful, it was sent to the upper layer and finally to the internet otherwise it is discarded, thus reducing the traffic on the Internet. An application-aware routing scheme for Big Data processing using SDN has been proposed by the authors Cheng and Wang in [21] to speed up the data shuffling over a network. They considered Hadoop Map Reduce for Big Data processing. The network topology employed is the Fat tree topology that is commonly used for scalability. SDN controllers receive the shuffling information from the Hadoop Controller and effectively allocate network resources. Results show that this scheme gives a better response than other similar schemes. The paper presents a Big Data network using SDN based IoT. The authors Xu et al. [22] states the problem associated a traditional network for Big Data transmission and how SDN can overcome them. The proposed architecture is flexible and meets the demands of Big Data transmission. As future work, they would like to implement the architecture with the simulation platform and improve SDN routing. Big Data transmission needs the support of the network. The authors Bedhief et al. in [23] presented a solution to overcome the heterogeneity of the network and IoT devices by adopting an SDN Docker-based architecture. SDN benefits like programmable configuration having a view of the overall network which helped to manage the heterogeneity of the network with docker. Thus it provides portability to the developers to create and deploy IoT applications easily.

In [24] Naik, the author of the paper, proposes a docker contained-based Big Data processing which is inexpensive and useful for everyone using multiple clouds.

Smart Grid: The authors Kaur et al. in [25], proposed a tensor-based Big Data management scheme for the dimensionality reduction of the data generated by smart devices in a Smart Grid System. SDN is used for minimizing the load and proper bandwidth utilization. In this scheme, data is represented in tensor form. Here Frobenius norm is applied to the high order tensors to reduce the reconstruction errors of the tensors. Next, an empirical probability based control scheme is designed to trace the best path for transferring the reduced data using SDN to achieve lower latency and higher QoS (quality of service).

Mobile Edge Computing: In the paper [26], the authors Wang et al. proposed an algorithm called Energy Efficient Sensor Selection and Routing (ESR), to reduce the energy consumption in SDN-IoT network where for Big Data processing Mobile Edge Computing (MEC) was applied. The algorithm comprises of three phases.

The overall energy consumption is reduced by cautiously finding optimal data reconstruction and aggregation, which is executed by SDN traffic engineering.

They have proved that ESR is a '$\alpha\ log|K|$' approximation algorithm, where K is the set of observed locations.

From the above, as discussed in the literature, it can be found that there are still major areas where further improvement needs to be done. Table 2 represents the proposed work and additional scope of improvement where the existing work can be further investigated.

4 Challenges and Issues Related to Big Data in SDN Based IoT

The extraction of meaningful data through Big Data analytic process in IoT is a challenge. This section provides some major challenges on this issue.

1. **Extraction:** There is a rapid generation of data as many IoT devices are connected to the Internet to provide accurate services. Not all data generated is useful that needs to be stored. These give rise to the problem for distinguishing between meaningful and redundant data. Therefore, proper mechanisms are required to filter only useful and meaningful data.
2. **Heterogeneous Data:** The heterogeneity of the IoT device producing data of different formats like text, voice, image, etc. needs to be handled. Noisy data need to be eliminated or corrected. Moreover, suitable data mining algorithms for each type of data need to be modified in order to deal with the IoT-Big Data.
3. **Storage:** Storage is another important concern in IoT-Big Data because the huge data need to be transmitted from the source to the server which eats up huge bandwidth as well as occupies large storage space. Data Redundancy is one of the biggest issues regarding storage [27]. Compressing the data and removing redundant data near the source will help to save both bandwidth and storage.
4. **Security:** The security of IoT devices has been an issue since long [28].
5. **Real-time Analysis:** Real-time analysis of the data from the sensors has become a mandate in most IoT environment. Achieving real-time response is little difficult because of the inherent network issues as well as the complexity of the data produced.
6. **Level of Analysis:** Another question of great concern to the Industry is the architectural level at which Big Data analysis should be done in the IoT environment.

5 Future Scope of Research

Although numerous problems related Big Data analysis of IoT in SDN based IoT were addressed by many other previous researchers, still there remains formidable amount of challenges in the area which needs further investigation for its efficient solutions. Some open research problems are presented below.

Table 2. Existing work with future scope.

Author	Proposed work	Future scope
Ding, G., Wang, L., Wu, Q. [13]	A practical approach to Big Data processing in IoT environment combatting issues like heterogeneity of data ,multidimensionality reduction of data etc.	More specific algorithms for IoT application purpose need to be investigated
Jabbar et al. [14]	Common form of computational tool for Big Data analytics using data fusion technique	Simpler and feasible query is needed for management of data and meta data. This is to be investigated out
Dinesh Kumar et al. [16]	Big Data analysis on health data using Hadoop and map reduce	Incorporating SDN based IoT will give an optimization of network utilization
Kang, Y. S. et al. [17]	Efficient data processing of RFID-IoT based data analysis using MongoDB	Enhancement needed for non-trivial query
Ghoneem and Kulkarni [18]	Adaptive scheduler for Hadoop Map Reduce Task	Sorting, searching on big clusters can be incorporated in the future as well as fairness in scheduling
Din et al. [12]	Architecture for smart cities using SDN enabled IoT-Big Data processing	More refined scheduling algorithm can be implemented to further reduce the Big Data processing
Bi et al. [19]	SDN architecture for smart cities to overcome time-constrained Big Data transfer scheduling	Support for different QoS requirement. Some lightweight action could be incorporated in the data layer
Kakiz et al. [20]	SDN-based IoT architecture using the lower layers for analysing the usefulness of data packets which needs to be retained thus reducing traffic at an early stage	Investigation on use of different types of SDN controllers those can be used to further strengthening the security of the system
Cheng et al. [21]	Application-aware routing scheme for Big Data processing using SDN	Different routing mechanisms need to be considered in delivering packets efficiently and achieving higher (QoS)
Xu et al. [22]	Big Data network using SDN based IoT	Implementation of the architecture with the simulation platform and improve SDN routing
Bedhief et al. [23]	SDN-docker based solution for heterogeneity of Big Data in IoT	The architecture has to be tested in different SDN controllers, which will be future work
Kaur et al. in [25]	Tensor-based Big Data management scheme for the dimensionality reduction of data in Smart Grid System	Implementation of this scheme in more systems
Wang et al. [26]	Algorithm for Energy Efficient Sensor Selection and Routing (ESR)	Practical implementation

1. Even if SDN controller helps in routing Big Data effectively in the IoT network, advanced protocols needs to be developed for the efficient utilization of network resources as well as their optimization and reliable operation.
2. Proper methodology for dimensionality reduction of the big IoT data has to be evolved out with lesser regeneration errors need to be investigated. Efforts should be given so that the developed methodology consumes lesser resources.
3. Further investigations are needed to facilitate SDN controllers to be able to control heterogeneous network more efficiently. Also methodology to be evolved so that

heterogeneity in smart devices and its developed heterogeneous data produced could be adequately handled.

4. Bringing down the computational requirement for resolving Big Data issues executable by the IoT devices, will help in improving the latency as well as bandwidth. This can be achieved through Edge computing or Fog computing which needs more further refinement in terms of further research investigation. Switches in SDN can be used as Fog nodes for the purpose. Efficient algorithm for the purpose could be investigated out.
5. **Level of Analysis:** Data generated from Infrastructure layer will be presented to the Application layer. There is a provision of data analysis at each of layer of the architecture. Development of efficient algorithm to work in both the layers for the purpose is also a challenge.

   (a) **Infrastructure Layer:** A low latency network performing Big Data analysis can be achieved in the Infrastructure layer. The data generated will be examined and processed within the same layer. Another advantage is that the required time for decision making in the upper layers will be greatly reduced based on this examined data.
   (b) **Network Layer:** The SDN-based network layer has controllers and switches which can be used for Big Data analysis as they are more powerful than the resource constrained devices in the Infrastructure layer for conventional IoT devices. Suitable Algorithms can be developed for the purpose using these resources which can resolve Big Data issues at shortest possible time.
   (c) **Application Layer:** In the application layer, Big Data analysis can be achieved using resources such as Hadoop, Apache Spark, Apache Storm, etc. running in the Cloud. These platforms can be accessed via APIs and the required data processing can be done there. These API's are light weighted and can be accessed from anywhere with proper authorization and authentication.

Investigations need to be carried out to develop suitable algorithms for resolving Big Data problem of IoT in the above mentioned architectural layers.

6. Since IoT system is a resource constrained system, research efforts are to made in the direction of developing lesser energy consumption methodology which will help optimal shuffle of Big Data in the network.

6 Conclusion

This paper discusses some past works related to Big Data issues generated by SDN based IoT architecture and how the previous workers tried to resolve this issue to facilitate Big Data analysis. Though this work has been initiated very recently so lot of research initiative are still pending to be resolved to be to give the SDN based IoT architecture a commercial shape. Some works have already been initiated which are discussed here as review model. Various potential challenges are also discussed in this paper which needed to be resolved to have smooth processing of the Big Data in IoT environment. Some key research works in the area of Big Data analysis in IoT have been presented in this paper. SDN structure of IoT plays a key role in IoT based Big Data analysis endeavour. This solution was possible due to the dynamic behaviour of the SDN controllers.

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